TESLA

TeV Energy Superconducting Linear Accelerator

THE HIGH POWER RF SOURCE

Abstract

The Tesla linear collider requires 600 pieces of 10MW L-Band klystrons operating at a pulse duration of 1.5ms and a repetition rate of up to 10Hz with an efficiency of the order of 70%. Since these performances are not achievable with a single beam klystron, a multi beam klystron (MBK), which uses many low perveance electron beams in parallel in one vacuum envelope, was developed by THOMSON TUBES ELECTRONIQUES). The advantage of this solution is the low voltage required and the high efficiency compared with a single beam klystron. THALES ELECTRON DEVICES (former Thomson Tibes Electronique) has developed and manufactured the TH1801. This MBK is in operation at the Tesla Test Facility at DESY, where it was tested at full pulse duration of 1.5ms. It reached 10MW at 117kV and 131A with an efficiency of 65%.

Multi Beam Klystrons

One of the parameters which determines the efficiency of a klystron is the perveance defined as $p=I/U^{3/2}$, where U is the klystron cathode voltage and I the klystron current. Comparison of various klystrons shows that the klystron efficiency increases with lower perveance. For a perveance of $2.0 \cdot 10^{-6} A/V^{3/2}$ the efficiency typically is 45%, whereas at $0.5 \cdot 10^{-6} A/V^{3/2}$ 70% seems to be feasible. The increase in efficiency is due to the effect that a low perveance results in a low space charge density which allows easier bunching and therefore better energy transfer from the DC to the AC component of the klystron electron beam.

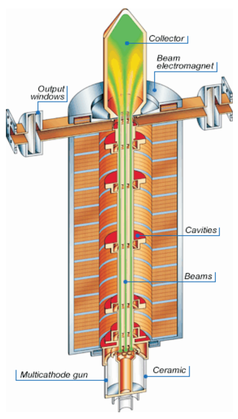
The attempt to construct a klystron with an efficiency of 70% and an output power of 10MW based on a single klystron electron beam with a perveance of $0.5 \cdot 10^{-6} A/V^{3/2}$ would result in a klystron beam voltage of 241kV. Since the required pulse duration is 1.5ms the construction of a klystron meeting these parameters seems to be impossible.

The solution is the use of several low perveance beams in parallel at lower voltage in one vacuum vessel. This technology is utilized in the multi beam klystron.

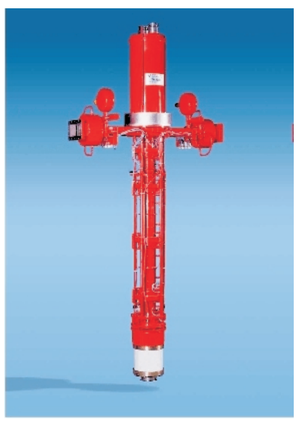
The TH1801

	Design
Operation Frequency	1300MHz
RF Pulse Duration	1.5ms
Repetition Rate	10Hz
Cathode Voltage	110kV
Beam Current	130A
HV Pulse Duration	1.7ms
No. of Beams	7
Total Perveance	$3.5 \cdot 10^{-6} A/V^{3/2}$
No. of Cavities	6
Max. RF Peak Power	10MW
RF Average Power	150kW
Efficiency	70% goal
Gain	48dB
Solenoid Power	4kW goal

Design Parameters of the TH1801



Principle Sketch of a Multi Beam Klystron

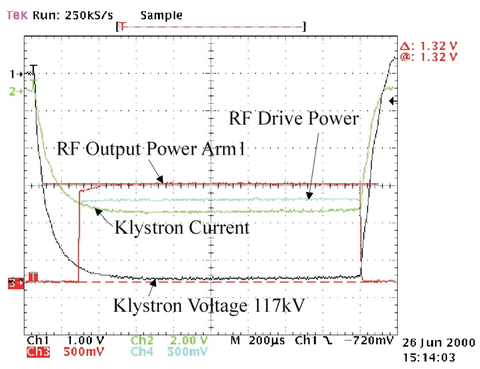


The TH1801 MBK

Cathode of the TH1801

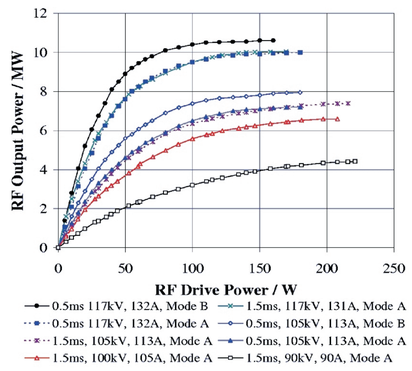
Test Results

Three MBKs have been produced until September 2001. All have completed the factory acceptance test at THALES, where they were tested to full RF power at shorter pulse duration of 0.5ms but higher repetition rate of 30Hz, since no modulator for a pulse duration of more than 0.5ms exists at THALES. The first klystron was installed in May 2000 in one of the HV modulators at the TESLA Test Facility (TTF) at DESY and then conditioned and tested to full RF power at full pulse width of 1.5ms, but lower repetition rate of 5Hz. It was in use for the operation of TTF till May 2001 for 5000h. Afterwards the second MBK was installed. It is in operation at full pulse width since May 2001for 2500h. The third MBK will be tested at full pulse duration in one of the new HV modulators now being installed at DESY.

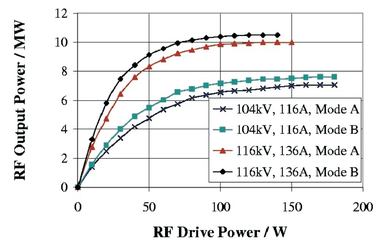


Waveforms at 10MW output power recorded at the first MBK during the long pulse test at DESY

The measurements were done using water loads at THALES and water cooled ferrite loads at DESY under matched load conditions with a VSWR smaller than 1.1. These measurements are indicated as Mode A. Additional measurements with mismatched water loads with a VSWR of 1.2 at optimum phase conditions were performed at THALES, indicated as Mode B.



RF output power as function of RF drive power of the first MBK for different operation conditions
Total Perveance $3.27 \cdot 10^{-6} A/V^{3/2}$
Max. Efficiency 65% in Mode A
Max. Efficiency 68% in Mode B
Solenoid Power 5.5kW



RF output power as function of RF drive power of the second MBK at 0.5ms pulse duration for different operation conditions
Total Perveance $3.44 \cdot 10^{-6} A/V^{3/2}$
Max. Efficiency 63% in Mode A
Max. Efficiency 66% in Mode B
Solenoid Power 5.5kW